Preliminary Hazard Analysis Report Sample

for

The BNL Center for Functional Nanomaterials

At
Brookhaven National Laboratory
Upton, New York 11973

January 8, 2004

Preliminary Hazard Analysis Report

for

The BNL Center for Functional Nanomaterials

Approved by:

____

Robert Hwang

CFN Director

Brookhaven National Laboratory

____

Michael Schaeffer

CFN Project Manager

Brookhaven National Laboratory

List of Terms

BNL	**Brookhaven National Laboratory**
CFN	**Center for Functional Nanomaterials**
CFR	**Code of Federal Regulations**
DOE	**U.S. Department of Energy**
DOT	**U.S. Department of Transportation**
FACP	**Fire Alarm Control Panel**
FHC	**Facility Hazard Categorization**
HIT	**Hazard Identification Tool**
ISM	**Integrated Safety Management**
ES&H	**Environment Safety & Health**
NSLS	**National Synchrotron Light Source**
PHA	**Preliminary Hazard Analysis**
PHAR	**Preliminary Hazard Analysis Report**
RQ	**Reportable Quantity**
SBMS	**Standards Based Management System**
TQ	**Threshold Quantity**
TPQ	**Threshold Planning Quantity**

PRELIMINARY HAZARD ANALYSIS FOR THE CFN AT BNL

1.0 EXECUTIVE SUMMARY

Brookhaven National Laboratory (BNL) is committed to the success of the Center for Functional Nanomaterials (CFN) in both mission objectives and the safety to its users, staff and public. To assure this success, a Preliminary Hazards Analysis (PHA) was conducted to predict the hazards that will be encountered during the operational and construction phase of the project. The PHA was also used to make an initial Facility Hazard Categorization (FHC). The initial FHC of the CFN has been determined to be a "Radiological Facility". Further analysis of radiation generating devices and the chemical inventory will be conducted as the design progresses and processes become more defined, this further analysis may change the initial FHC, likely reducing it to an industrial facility categorization.

Principal Investigators (PI's) from each cluster area of the facility were surveyed to identify potential hazards with the equipment, operations and ancillary equipment used in their respective clusters. Along with completing a detailed survey of potential hazards, equipment data from vendors, review of current chemical inventories, and review of current similar operations was conducted. This review provided a good insight into the potential hazards that will be encountered in the CFN and is instrumental in the development of necessary design controls. Since this process was started early in the conceptual phase, hazards and controls identified were provided to assist in the Title I design.

Due to the dynamic and cutting edge nature of nanoscience technology changes are anticipated in the instrumentation/equipment over the course of facility construction. This will necessitate the refinement of this analysis to assure that unreviewed hazards are not introduced into the facility. The original PHA was conducted in April 2003 very early in the conceptual phase to support the Conceptual Design Review (CDR). The analysis was revisited in December 2003 to coincide with the 75% Title I review. The Title I review codified those aspects important to the ESH design of the facility and introduced some changes requiring ESH assessment. These changes are addressed in this updated PHA and include:

- Re-location of the facility
- Further refinement of the chemical and gas inventories
- Elimination of central supplied propane system
- Use of common utility corridors
- Introduction of manifold exhaust system for laboratory fume hoods
- Refinement of the toxic gas distribution and control methodologies

2.0 INTRODUCTION

The purpose of this Preliminary Hazard Analysis (PHA) is to identify significant facility operational hazards, analyze their consequences, and evaluate proposed methods and systems to manage those hazards in support of the development of the Conceptual Design Report (CDR) and subsequently the Title I design. This is done by developing a description of the proposed facility, its support systems, and proposed safety systems using the early design concepts as its basis. Facility hazards are identified and analyzed with the objective of identifying and evaluating safety functions and systems that will be relied upon to manage the hazards. Controls and commitments are established to help ensure that safety functions are realized through the design and operational process. This document establishes the initial safety basis for the facility.

The purpose of the Center for Functional Nanomaterials (CFN) at BNL is as follows:

The Center for Functional Nanomaterials (CFN), at Brookhaven National Laboratory (BNL), will be a user facility for the characterization, synthesis, and theory of nanoscale materials. The CFN will be located south of the NSLS and south of Brookhaven Avenue. The location is based upon several criteria, including the ability to comply with environmental criteria, the ability to meet research mission objectives and the physical proximity to collaborative BNL research facilities. The CFN's nanoscience program is aimed at fully understanding functional materials and their chemical and physical response at the nanoscale and, thus, enabling the atomic-level tailoring of new types and forms of nanomaterials.

The CFN will feature extensive research into the design, synthesis, and characterization of nanostructures. Its centerpiece will be an array of five unique, state-of-the-art laboratory clusters, a cluster devoted to Theory and Computation and a set of end stations on NSLS beamlines, which, along with the associated scientific and technical staff, will be available to users from academic, government, and industrial laboratories. The clusters (or facilities) will provide users with the breadth of tools needed for nanoscience research at a single location.

3.0 DESCRIPTION OF FACILITY AND OPERATIONS

This section describes the proposed facility and its operations and is the basis for the overall analysis. A more detailed design description is provided in the 75% Title 1 design document. The level of description provided here is designed to support the assessment of hazards and hazard mitigation

3.1 Facility Description

The following is an abbreviated description of the physical facility and associated supporting and utility systems. The reader is referred to the Conceptual Design Report (CDR) and the 75% Title I submittal for detailed descriptions. The purpose of this section is to facilitate the basis understanding of the facility and help place the discussion of hazards and their controls in context. Additionally, this kind of information is traditional for a PHA and allows the PHA to be used without the need for the companion design documents such as the CDR and/or the 75% Title I upon which the PHA is based.

3.1.1 Basic Structures

The facility will provide approximately 94,500 square feet of general laboratory, wet laboratory, clean rooms, conference areas, office, and support space. The two-story building will be located on a 9-acre site south of Brookhaven Avenue across from the current National Synchrotron Light Source (NSLS) and is bordered on the north by Brookhaven Avenue, on the south by Bell Avenue and on the west by Rochester Street and on the east by Grove Street. This facility will provide space for scientific staff from Instrumentation, Physics, NSLS, Material Science and Chemistry.

The project will include:

- Single person offices
- Multi-person offices
- Flexible Office Space
- Electron Microscopy Lab Spaces
- Proximal Probe Lab Spaces
- Nanopatterning Lab Spaces
- Materials Synthesis Lab Spaces
- Ultrafast Optical Source Labs
- Theory & Computation Lab Spaces
- General Purpose Labs
- Conference Space
- Service and Support Space, including mechanical equipment area, toilet rooms, corridors, and other support spaces.

The building will incorporate human factors into its design to encourage peer interactions and collaborative visits by staff around the Laboratory. In addition to offices and laboratories, it will house “interaction areas” for informal discussions and lunchrooms on each floor to foster scientific discourse. This design approach is commonly regarded as the state-of-the-art in research facility design. The laboratory areas will incorporate lessons learned from other recent BNL laboratory construction, other nano laboratories built across the nation, as well as compliance with current regulatory and consensus standards for contemporary laboratory design.

The new laboratory building consists of a structural steel frame with bays of metal decks with concrete fill, all supported on reinforced concrete footings and foundations. The ground floor will be a concrete slab on grade in various thicknesses to eliminate vibration between each laboratory and surrounding areas. The roof will be metal deck with concrete fill and roof insulation, with a 4-ply membrane roofing system. Exterior wall treatment shall be architectural panel and operable double-glazed aluminum windows. In addition, the walls will be designed to eliminate electro-magnetic/radio frequency interference from external sources.

The CFN will utilize a service galley concept that will bisect four of the clusters and parallels the fifth cluster area. The service galleys will contain the laboratory’s main supply and exhaust air distribution; main piped utility distribution, and electrical branch panel boards. Each service galley will provide two 3’ wide zones of floor area designated to accommodate ancillary laboratory support equipment, which are noise, vibration, heat and/or EMI/ELF generators that are required to be separated from sensitive equipment. This service chase design is especially beneficial to the ESH of the entire facility for several reasons; including keeping unnecessary equipment out of the research labs and pedestrian halls, facilitates delivery of laboratory gases, power and HVAC and overall promotes good housekeeping practices.

The entire laboratory building will be climate controlled with an electronically controlled heating, ventilation and air conditioning system linked to BNL’s site-wide energy management control system (EMCS). Utilities will include: steam and condensate, electrical power, communication, fiber-optic data-link, fire protection and detection, sanitary system, potable water, and storm water drainage.

The BNL Center for Functional Nanomaterials will be in close proximity with collaborative BNL research facilities in Buildings 725 (NSLS), 535 (Instrumentation), and 480 (Materials Science) to complement the existing functions of these facilities. These facilities are key interdisciplinary participants in Nano research.

The building will include five major laboratory clusters: Nanopatterning, Materials Synthesis, Electron Microscopy, Ultrafast Optical Sources and Proximal Probes. In addition, the Center will also operate a beamline cluster at the NSLS and a Theory and Computation cluster housed in the facility.

3.1.2 Utilities

3.1.2.1 Electrical Power

Normal power will be provided to the CFN via existing 13.8 kV feeder 600-2. A new 6-way, 15 kV, double bussed SF6 pad mounted switch will be used to serve two building substations. The two transformer substations will each consist of a 15 kV outdoor walk-in type fused load interrupter switch, a 2500 kVA 13.8 kV – 480/277V oil filled substation type transformer, and a secondary air terminal section. Provisions are provided in the 6-way pad mounted switch for the installation of a future “alternate” feed to the CFN. This will allow for ease in maintenance, increased system reliability, and rapid reinstatement of power in the event of an unplanned outage.

Incoming supply distribution equipment will consist of one double ended, 4000A, 480Y/277 volt, 3 phase, 4-wire switchgear located in the main electrical room. To reduce the possibility of power disturbances affecting sensitive electronic equipment, one side of the switchgear will serve only laboratory equipment. The other side of the switchgear will serve house power and mechanical equipment that will remain isolated, eliminating power disturbances to the sensitive equipment.

Each pair of laboratory modules will be provided with a 50A and a 100A 208Y/120 volt panel board located in the service galley adjacent to the lab. These panels will be served via dedicated shielded isolation type transformers. This arrangement will facilitate isolation of sensitive equipment from non-sensitive equipment.

All power system grounding will be in accordance with the NEC and IEEE standards. A separate green insulated equipment ground will be provided in all feeders and branch circuits. In addition, isolated equipment grounding conductors will be provided for sensitive equipment circuits. Each lab module will be provided with an instrument reference ground bus and will be insulated from all other grounds except at the single point connection to the power system ground bus.

All primary service feeders will be run in underground electrical duct banks, steel reinforced where necessary. All interior branch circuit feeders, will be copper conductors, 600 volt insulated cable, installed in NEC compliant electrical raceways and designed to eliminate any EMI/RF interference.

3.1.2.2 Heating, Ventilation and Air Conditioning Systems

The Mechanical Equipment Rooms and Power Supply Room will be air-conditioned utilizing ductless split system type air conditioning units. The Offices and laboratory areas will be air conditioned with central station HVAC units located in the mechanical equipment penthouse utilizing central steam and central chilled water for heating and cooling.

Air handling units serving laboratories will be 100% outside air, constant volume terminal reheat type systems. Variable volume terminal reheat air handling units will serve offices, conference rooms, and other non-critical areas supplying 15 air changes per hour. A separate variable volume air-handling unit will serve the lobby to provide building pressurization. The clean rooms will be served by several clean room designed air-handling units to provide the required cleanliness. The Electron Microscopy rooms will have their own circulating air handler supplying 120 air changes per hour to assure ± 0.1 deg C accurate temperature control. Both, the high accuracy temperature controlled labs and the clean room units, will have their own make up air units. Air handling units will be located in penthouses above the laboratories and clean rooms.

Exhaust fans will be provided for fume hoods, general laboratory exhaust, toilet rooms, mechanical and electrical rooms, process equipment, hazardous storage and other areas requiring exhaust.

Laboratories will be provided with individual fume hoods that will have a negative pressure relationship to adjoining areas. For flexibility, cost effectiveness, and for allowing heat recovery and stand-by capability, laboratories will have central manifolded exhaust fans. Risers will be connected to an exhaust manifold in the penthouse. Hood exhaust branches and general exhaust ducts will have flow control devices to minimize balancing requirements during future changes. Exhaust fans of laboratories will discharge at 4000 feet per minute as per BNL and Industrial Ventilation guidelines to prevent re-circulation and will be provided with filtration (HEPA and/or charcoal) where necessary. For redundancy, stand-by lab exhaust fans will be provided.

A manifolded exhaust system has many advantages as well as introduces a potential concern of incompatible materials being exhausted at the same time via different hoods but mixing in the common exhaust ductwork. The advantages of common manifolding outweigh the disadvantages and include:

- Enhanced dilution – the mixing of general room exhaust and hood exhaust multiplied by several manifold systems increases the dilution factor.
- Minimize personnel exposure - the elimination of multiple dedicated fume hood exhaust fans reduces the overall time that maintenance personnel must spend on the roof of the building, which is a potential exposure point.
- Redundancy – using a set of two or three exhaust fans to support the combined building exhaust system eliminates the problem of system failure since there is always a backup fan in service, it also allows maintenance and inspection of system components without shutting down the entire system.
- Facility flexibility – future flexibility driven by changes to the research mission can be more easily accommodated.
- Emergency power – it is more efficient and easier to connect a manifold system to emergency than multiple stand-alone systems.
- Heat recovery – a manifold system lends its self to greater heat recovery mechanisms.

- Minimize re-entrainment – having a single exhaust on the roof allows for greater separation from the fresh air intake of the facility.
- Energy Conservation – since all hoods will not be operating at all times, this allows for the system to be designed smaller and to be operated with less total airflow.

The facility will restrict the manifolding of those fume hoods that would be used for radiological materials or shock sensitive materials (i.e., perchloric acids, metal azides). These materials will have independent exhaust systems specially designed for the specific material. The experimental review process will evaluate all materials used in the laboratories prior to their use to assure compatibility.

The facility will incorporate a Ventilation System Emergency Shutdown System (VSES). The VSES will provide emergency shutdown of the clean room recirculating air-handling units serving the clean room. Emergency pushbutton stations will be located at clean room exits. Horns and strobes (distinct from the fire alarm system) will be located throughout the clean room and the mechanical room serving the clean room. Upon activation of an emergency pushbutton, the horns will sound, the strobes will flash, and the recalculating unit will shutdown. The exhaust fans and make-up units will continue to operate

3.1.2.3 Process Cooling Water System

A process cooling water system will be provided for experimental cooling. The system will include an expansion tank, two recirculation pumps, heat exchangers, high efficiency filters, instrumentation and distribution piping. Process cooling water will be supplied to laboratories at 55 deg F.

3.1.2.4 Deionized Water System

Deionized water is planned for only a few of the laboratories. The deionized water will therefore be produced locally from laboratory cold water by means of a local RO/DI and membrane filter system, dedicated to the respective laboratory. A central deionized water system will not be provided for the facility.

3.1.2.5 Compressed Air

The CFN will be tied into the site wide 100-psig compressed air system. To assure clean, dry compressed air to the laboratories, the incoming service will be provided with heatless regenerative desiccant dryers, particulate filters and pressure regulators.

3.1.2.6 Fire Protection, Suppression & Potable Water System

The building occupancy classification for the CFN is based on the Building Code of New York State (BCNY). An analysis of the BCNY and its application to the CFN was completed during the Title 1 design effort. The classification of the building and subparts of the building were carefully selected to assure an adequate level of functionality, occupant protection, code compliance as well as affordable building design. The occupancy of the overall building has been classified as a Business (B) occupancy, based on programmatic staff’s statements on the amount of hazardous materials and chemicals anticipated to be used. Certain areas within the structure may be classified as higher areas (“H” occupancy) including the gas cylinder storage rooms and the clean room due to more concentrated quantities of hazardous materials and chemicals. A “controlled” area concept, as allowed by BCNY, will be utilized to provide the greatest amount of flexibility and control of materials. The controlled area designations will require administrative procedures to assure that each control area does not exceed the limits prescribed in the BCNY.

Fire Protection and potable water will be supplied from the BNL site wide potable water system. The system is supplied by several deep wells and is stabilized by two elevated water storage tanks (one 1 million gallon and 350,000 gallon capacity). The wells have electric primary drivers and a limited number have backup internal combustion drivers. The system can sustain three days of domestic supply and a maximum fire demand (4000 gpm for 4 hours) for BNL with two of the system's largest pumps out of service and one storage tank unavailable. The piping distribution network is well gridded to reduce the impact on any one building by a single water main break.

The primary water supply feed into the building from the site potable water supply will be a combined domestic/fire protection connection. Due to the high value of the facility, reliability of water supplies will be improved by providing a second feed into the fire protection system from a separate main. Each feed into the building shall be hydraulically sized to handle the total combined water supply requirements of the domestic and automatic sprinkler/standpipe systems. To allow uninterruptible water supply for the building during potable water main repair or maintenance at the street, a means to isolate the new building feeds shall be provided at the street. If an existing control value in the potable water mains does not exist between the two new main then a control valve shall be installed.

The potable water supply feeds to the automatic fire sprinkler and standpipe systems shall be protected against backflow by a double check valve assembly or a reduced pressure principle backflow preventor as required by Section 608.16.4.of the Plumbing Code of New York State. (PCNY).

A fire sprinkler system will be provided throughout the building meeting the requirements of NFPA 13 “Standard for Installation of Sprinklers” and will be hydraulically designed to provide a 0.15 gpm/sq. ft. density over 2500 square feet with 250 gpm reserved for hose streams (hydraulic performance has been derived from Factory Mutual Global Standards). Piping network design will be matched to water supply profiles based by water flow test on the BNL water supply system

A fire standpipe system will be provided throughout the building meeting the requirements of NFPA 14 “Standard for the Installation of Standpipe and Hose Systems.” The system will be a “Class 1 System” as defined by NFPA 14. Hose connections shall be located in each of the rated stairs on each of the floor landings including the roof access stair landing.

A fire department connection shall be located in the front of the building. The fire department connection shall be interconnected with the automatic sprinkler and standpipe systems. It shall be designed and hydraulically calculated in accordance with NFPA and BCNY.

Fire hydrants are provided within 300 ft. of each facility (there are some exceptions to the 300ft. distance on the BNL site but not in the vicinity of the CFN). Frost proof hydrants are needed since the frost line extends to 4 feet below the surface in the winter. BNL and the local Suffolk County Fire Departments use National Standard Thread couplings. BNL's Plant

Engineering Division maintains the water supply system. BNL's Fire/Rescue Group conducts valve inspections on the distribution system to ensure reliability of firefighting water supplies.

3.1.2.7 Fire, Alarm and Detection

A fire alarm system will be provided meeting the requirements of NFPA 72 "National Fire Alarm Code". A new fire alarm control panel (FACP) will be provided for the facility and located inside the main building entrance lobby for easy fire department access. The fire alarm system will monitor waterflow on the sprinkler system, supervise the sprinkler valves, and installed detection systems. Audible/visual alarm notification devices will be provided to alert building occupants. Manual fire alarm pull stations will be provided at all building exits and at all exit stairs from level 2. . Photoelectric area smoke detectors will be provided in the air handling systems as required by NFPA 90A. Smoke detection will be provided in areas where highly sensitive electronic equipment, valued over $250k, will be located (as per current DOE Orders). Combination audible/visual alarm and/or visual only annunciation devices will be provided throughout the corridor system, in each lab, in each clean room bay, and in most rooms other than single person offices facility to alert the occupants. Fire alarm and supervisory signals will be transmitted to BNL's Fire Rescue Group via the Site Fire Alarm System.

All fire alarm and system supervisory signals are monitored by the Fire/Rescue Group at Building 599. A secondary monitoring station is located at Security (Bldg 50). Typically, the Fire Rescue responds to the scene of a BNL facility within 5 minutes of an alarm. Fire Rescue is staffed and equipped for incipient stage structural fire fighting. BNL is a member of the Suffolk County Fire and Federal Mutual Aid System. This provides assistance from 120 other fire departments in Suffolk. Fire Rescue also provides emergency medical services via a NY State Certified Basic Life Support Ambulance. Additionally, Fire Rescue is the on site hazardous materials response team. They are trained as Hazardous Materials Technicians as per NFPA.

The CFN will be provided with fire extinguishers in compliance with NFPA 10.

3.1.2.8 Instrumentation and Control Systems

The CFN laboratory spaces will require precise control of their environmental conditions to achieve optimal performance of the research instruments. As such, standard commercial HVAC controls typically utilized for office environments will not be adequate to meet these requirements. It is anticipated that CFN laboratory spaces will be monitored and controlled by a combination of commercial HVAC controls and industrial grade process controls linked to a direct digital control system specially programmed to serve the precise requirements of these lab spaces. Overall performance and monitoring of this system will be linked and continuously monitored by the BNL site wide Energy Management Control System (EMCS).

3.1.2.9 Communications

The communications systems provide the distribution of data and telephone communications. Generally, these provisions allow for the installation of cabling, equipment, and tie-in terminations by BNL Communications Division.

A new telephone service will be provided to the facility serving the laboratory, office and supporting Mechanical/Electrical Rooms. The service will be provided via new underground concrete encased duct bank to the mechanical room.

A new fiber optic based network data cable and support equipment will be provided to the new facility via a new underground concrete encased communication duct bank to the mechanical room.

3.1.2.10 Facility Access Control

The CFN will be equipped with magnetic card readers to restrict access to authorized personnel only. The card readers will be located at each building entrance and at each laboratory entrance.

3.2 Cluster Descriptions and Major equipment

3.2.1 Nanopatterning

The activities in this cluster will be relatively similar to semiconductor fabrication, albeit at nanometer scale. Operations include photolithography and electron beam writing, as well as chemical vapor deposition and etching

In addition, this cluster will include laboratories for pattern transfer, including thin-film deposition and etching equipment. The facility will be used to investigate novel nanoscale-fabrication processes, perform patterning on nano-objects and arrays for characterization and measurement, and fabricate nanameter-measuring tools. Linewidth measurements of the fabricated structures will be accomplished with high-resolution scanning electron or proximal microscopes. The laboratories required will be clean rooms at Class 100 and Class 1000. Photolithography and E-beam equipment are extremely sensitive to vibration and fairly sensitive to temperature and humidity fluctuations. Control of magnetic fields and radio frequency interference are also required. The operations in this cluster will require the use of some toxic, flammable and explosive gases.

Proposed major equipment:

Instrument/Equipment	Principal Use	Comments
JBX 9300FS Electron-Beam Lithography Pattern Generator	Fabricate nano-scale trenches in substrates	x-ray leakage < .5 mrem/hr; Accelerating voltage 100Kv (thermal field emission gun); Beam current $5x10^{-11}$ to $1x10^{-7}$ A
FEI Nova 200 Focused Ion Beam Lithography Tool	Integrates immersion field emission scanning electron microscope (FE-SEM) with focused ion beam (FIB) for cross sectioning and TEM preparation	x-ray leakage < .1 mrem/hr @ 10cm; stray magnetic field < 0.1µT. Pt gases, iodine gases, naphthalene
Trion Phantom Mini-lock II DRIE Silicon Etch System	Deep reactive ion etching of silicon	5kw RF generator

Instrument/Equipment	Principal Use	Comments
EVG 101 Photo resist Development Station	Coating process for thin film and thick resist applications	Needs exhaust Solvents, pressurized system
Molecular Imprints Imprio 55 Nanoimprinter	Fabricate nanoscale patterns in specialized photoresists	No special requirements Solution includes; Silicon, acrylate, alkyl acrylate, di functional acrylate and sensitizer

3.2.2 Ultrafast Optical Sources

The Ultrafast Cluster will house and develop a suite of techniques important to understanding structure and dynamics of nanostructured systems down to femtosecond time scales. A few laser systems will serve a number of experimental stations, configured for different nonlinear optical probes and femtosecond pump-probe geometries, offering researchers the broadest range of available techniques. Many developing ultrafast techniques that are widely perceived as showing great promise in nanoscience applications, such as terahertz spectroscopy, novel single-shot measurement techniques, ultrafast near-field microscopy, and ultrafast short-wavelength sources, are also interesting scientifically in themselves, so the laboratory is also structured for the active development of these techniques and their rapid inclusion as methods available to researchers at the Center.

The Cluster can be roughly divided into Nonlinear Optical Probes, Femtosecond Pump-probe Methods, and New Sources and Techniques. Nonlinear Optical Probes primarily exploit the high peak intensity of ultrafast systems. The nonlinear response of the sample to the strong optical fields is strongly dependent on local composition and structure, creating a probe which can isolate surface effects from bulk response, interrogate interfacial dynamics at the boundary of nanostructures, identify local conformational changes within a sample, probe local fields, or reveal other symmetries. Femtosecond Pump-probe Methods exploit the ultrafast character: nanostructured systems show interesting dynamical behavior on time scales from femtoseconds to milliseconds and beyond, and optical pump-probe techniques provide unique ways in which to study phenomena over this whole range. New Sources and Techniques develop new methods and apply them to nanostructured systems.

This cluster is made up of two laser laboratories. Some work is carried out at atmospheric pressure, some in vacuum or ultra-high vacuum. The majority of experiments will be carried out on optical tables.

Proposed major equipment:

Instrument/Equipment	Principal Use	Comments
Utlra-fast, multi-kilohertz laser systems	Structure and properties characterization	Class IV visible and near-IR laser.
Tunable ultra-fast pulses for linear and nonlinear spectroscopy	Structure and properties characterization. Source Development	Ultraviolet to far-IR class IIIb-IV laser radiation
Ultra-fast detectors and advanced metrology	Structure and properties characterization. Time-resolved technique development	

Instrument/Equipment	Principal Use	Comments
Surface science experimental station	Surface dynamics, catalysis, structure and properties characterization	
Power Amplifier	Structure and properties characterization. Source development	Class IV laser radiation (near IR)
Monochromator	Diagnostics. Structure and properties characterization	
Streak Camera	Diagnostics. Structure and properties characterization	
3 GHz Digital Oscilloscope	Diagnostics	
500 MHz Oscilloscope	Diagnostics	

3.2.3 Electron Microscopy

This cluster will operate a number of advanced electron microscopes including a combined STM/TEM, in addition to existing high resolution TEM instrument. These instruments will be dedicated for structure and property measurement of nanometer scale materials, such as nanoparticles and wires. Nanostructured samples will be prepared in an adjacent ultra-high vacuum chamber and then transferred directly into the TEMs.

Proposed major equipment:

Instrument/Equipment	Principal Use	Comments
STEM (300-400kV) (Nion Ultra STEM 200)	Structure and property measurement	Built in STM with piezo stages (spatial resolution <0.8A, energy resolution < 0.1eV
High-resolution magnetic microscope (300 keV FEG TEM, FEI Tecnai G2 Polara)	Structure and property measurement	
Imaging plate reader	Structure and property measurement	
Sample Lab including: diamond wheel saws, band saws, and wire saws.	Sample preparation	Liquid coolant/lubricant
Ultrasonic cutter	Sample preparation	Liquid used as ultrasound transmission in medium and as a coolant/lubricant.
Electropolisher	Sample preparation	Liquid chemical polishing and etching agents
Ion Mills	Sample preparation	Ion generation in vacuum, ion gun high voltage (5kV), compressed gases
Lapping and polishing systems	Sample preparation	Polishing papers, cloths, agents with removed material (industrial/hazardous waste)
Optical Microscopes		No issues

3.2.4 Materials Synthesis

The materials synthesis cluster is designed to provide capabilities for advanced functional materials synthesis including bulk, thin-film, and nanofabricated materials. The laboratories are typical to what would be used in a chemistry and biology set up. The major analytic equipment will include, an x-ray diffraction system, a thermal properties (TGA) capability, and a magnetometer. The facility will also include the capability for the synthesis of small molecule and polymeric thin films by vapor phase growth and spin casting.

Thin film fabrication is facilitated with a MBE system, a pulsed laser deposition system (PLD) for oxide films, and a basic evaporator for putting down metal layers. A wet chemistry preparation lab will be used for generation of uniform precursors and for fabrication of nano-particles.

The characterization tools included within these laboratories are essential to the nano-fabrication effort. <u>A metallography lab will allow the evaluation of microstructures, as well as the preparation of specimens for scanning electron microscopy</u> (note: this function is now part of PP/EM laboratory!). Conventional x-ray diffraction will be used for preliminary characterization. Magnetic and thermal characterization will be utilized extensively. The NMR will be a generator of magnetic fields; simultaneously it will be sensitive to ambient electromagnet interference.

Proposed major equipment:

Instrument/Equipment	Principal Use	Comments
Expt. Xray diffractometer (tabletop)	Characterization of samples	x-ray generator
Molecular Beam Epitaxy (MBE)	Fabrication of film samples	(Veeco Applied Epi Mod. Gen.II), growth chamber
Glove boxes (3)	Process samples needing controlled atmospheres	
Thermal measurement lab (TGA, DTA, DSC)	Observe reactions and phase changes as function of temperature	Small samples (~100mg), furnace with controlled atm.
NMR, Bruker	Determine crystalline and molecular structures	High magnetic field, radio frequency cryogenics
Vacuum evaporator	Deposit metallic layers	High voltages for e- beam
PPMS (properties in magnetic field)	Properties of materials subject to magnetic field and low temperatures	High magnetic field, cryogenics
Vibrating sample magnetometer	Magnetic properties in field	High magnetic field, furnace, cryogenics

3.2.5 Proximal Probes

The microscopy performed in this cluster relies on scanning probes using nanotips rather than electron beams. Many of the experiments that will be carried out in this cluster will involve the synthesis of nanomaterials on solid surfaces that will be used as templates. For example, this will be the route for preparation of carbon nanotubes, self-assembled molecular materials, and nanocatalysts. It is expected that, in the first stage of the work, the functional materials will be characterized in the cluster using atomic-force microscopy, scanning-tunneling microscopy, as well as an advanced surface analysis instrument. More experimental surface probing will also be done at the NSLS. Combining these techniques, researchers will be able to determine the structure and composition of films.

While some of the instruments are manufactures, others will be built experimentally in house. The environmental sensitivities are similar to electron microscopy, although not quite as severe. Some toxic gases will be used in these labs.

Proposed major equipment:

Instrument/Equipment	Principal Use	Comments
-UHV Variable Temperature Scanning Tunneling Microscope	Material preparation & characterization	Cryogen (N2, He); Gases
-UHV Low Temperature, Scanning Tunneling Microscope	Material preparation & characterization	Cryogen (N2, He); Gases
-Environmental, Combination STM/AFM (Digital)	Material characterization	
-LEEM	Material preparation & characterization	Cryogen (N2, He); Gases
UHV Nanoprobe (Omicron)	Material preparation & characterization	Cryogen (N2, He); Gases
Combination Near-Field SPM (Nanoics)	Material characterization	Laser
Combination Optical Microscope and Ultra Objective SPM Head (Accurion)	Material characterization	Laser
Raman Spectroscopy	Material characterization	Laser
UV-VIS Raman Microscope (Renishaw)	Material characterization	Laser
FT-IR, FT-Raman, IR Microscope (Bruker)	Material characterization	Laser
UV/VIS/NIR Spectrometer (Varian Cary 5000)	Material characterization	Laser

3.2.6 Theory and Computation

This cluster will maintain the capability (hardware and software) to interpret experiments carried out at the nanocenter. In addition software to assist in the designing and synthesizing of new nanostructured materials. A suite of software will be developed in the following areas:

- Density functional codes for crystals and crystalline surfaces,
- Quantum chemistry codes for finite clusters,
- TEM, X-ray analysis codes,
- Visualization, graphics, molecular mechanics.

Proposed major equipment:

Instrument/Equipment	Principal Use	Comments
Dedicated workstations	Computing support	Commercial unmodified equipment
Linux Cluster nodes	Computing support	Commercial unmodified equipment
Software	Analysis	Commercial and developed on site, analysis only will not control building or safety systems

3.2.7 CFN Endstations at NSLS

The seventh "cluster" will be modified beamline endstations located at the NSLS, which will be devoted to small-angle x-ray scattering and x-ray microprobing. The hazards and controls of these endstations will be covered under existing NSLS design and operational procedures.

4.0 HAZARD SCREENING

Preliminary hazard screening and assessment of the hazards associated with the CFN has been achieved by reviewing the proposed activities, equipment, instrumentation, chemical inventories, as well as interviewing the Principal Investigators and evaluating their current laboratory hazards and operations. The BNL "Hazard Identification Tool" (HIT) http://www.bnl.gov/sbms_office/hid/ was used to identify and document these potential hazards for each cluster. The potential hazards identified for each cluster are summarized in tables 4-1 through 4-6

Table: 4-1

CLUSTER: Nanopatterning		
HIT Screening Question*	**HAZARD**	**SOURCE**
1.	Accelerators or RGD's	RGD's radiation area capable; incidental x-rays
2.	Radioactive Material	None
3.	Explosives	None
4.	Lasers	None
5.	Chemicals, toxic materials	Carcinogens, Hydrofluoric Acid, Peroxide Forming Chemicals, Cryogens, Compressed gases (Hydrogen, Nitrogen, Helium, Silane Ammonia, and Nitrous Oxide).
6.	Electrical	High voltage power supplies, hi amps, potential hot work,
7.	Mechanical Hazards	Portable hoist, power tools
8.	Non-ionizing radiation	5 Kw RF; stray magnetic fields < 0.1 μT
9.	Thermal Hazards	Cryogens
10.	Pressure Sources	>15psig, compressed gases
11.	Noise	None
12.	Additional Hazards: biological, confined space, elevated	Potential for biological samples, small quantity, sealed
13.	Site built instrumentation	None
14.	Extended Operations	Work outside normal hours, will not be attended
15.	Environmental	Hazardous waste, industrial waste
16.	Design controls, interlocks, ventilation	Ventilation systems HEPA
17.	Facility Safety Systems	Sprinkler system; lightning/surge protection; compressed air, gases

* Corresponds to the Hazard Identification Screening Questions

Table: 4-2

CLUSTER: Ultrafast Optical Source		
HIT Screening Question*	**HAZARD**	**SOURCE**
1.	Accelerators or RGD's	RGD's radiation area capable, intentional x-rays
2.	Radioactive Material	None
3.	Explosives	None
4.	Lasers	Class 3b, 4, 2, 1, modified, laser dyes
5.	Chemicals, toxic materials	Carcinogens, Combustibles, Reproductive Hazard Chemicals, Cryogens, Dry Ice, Compressed Gases (Hydrogen, Nitrogen, Helium, and Fluorine mix)
6.	Electrical	High voltage power supplies, hi amps, potential hot work, locally modified/built, ESO approval required
7.	Mechanical Hazards	None
8.	Non-ionizing radiation	Stray magnetic fields
9.	Thermal Hazards	Cryogens
10.	Pressure Sources	>15psig, >1.0 kilojoule
11.	Noise	None
12.	Additional Hazards: biological, confined space, elevated	None
13.	Site built instrumentation	Modified commercial equip
14.	Extended Operations	Work outside normal hours, will be attended
15.	Environmental	None
16.	Design controls, interlocks, ventilation	Interlock systems (laser lab); potential medical monitoring
17.	Facility Safety Systems	Sprinkler system; lightning/surge protection; compressed air, gases.

* Corresponds to the Hazard Identification Screening Questions

Table 4-3

CLUSTER: Electron Microscopy		
HIT Screening Question*	**HAZARD**	**SOURCE**
1.	Accelerators or RGD's	Incidental x-rays
2.	Radioactive Material	None
3.	Explosives	None
4.	Lasers	None
5.	Chemicals, toxic materials	Carcinogens, Pyrophoric, Toxic Gases, Combustibles, Sensitizers, Exothermic

CLUSTER: Electron Microscopy		
HIT Screening Question*	**HAZARD**	**SOURCE**
		and Endothermic, Cryogens, Dry Ice, Compressed Gases (Hydrogen Nitrogen, Helium, and Fluorine Mix)
6.	Electrical	High voltage power supplies, hi amps, potential hot work
7.	Mechanical Hazards	Pneumatic lift, rigging; fork truck; powered hand tools.
8.	Non-ionizing radiation	None
9.	Thermal Hazards	Cryogens
10.	Pressure Sources	Cryogen >160 L, >15 psig
11.	Noise	None
12.	Additional Hazards: biological, confined space, elevated	None
13.	Site built instrumentation	Modified commercial equip
14.	Extended Operations	Work outside normal hours, will be attended
15.	Environmental	Hazardous waste; industrial waste
16.	Design controls, interlocks, ventilation	Local exhaust; interlock systems (laser lab)
17.	Facility Safety Systems	Sprinkler system; lightning/surge protection; compressed air, gases.

* Corresponds to the Hazard Identification Screening Questions

Table 4-4

CLUSTER: Materials Synthesis		
HIT Screening Question*	**HAZARD**	**SOURCE**
1.	Accelerators or RGD's	RGD's radiation area capable, intentional x-rays
2.	Radioactive Material	None
3.	Explosives	None
4.	Lasers	3b, 4, 2, 1, modified, laser dyes
5.	Chemicals, toxic materials	Carcinogens, Pyrophoric, Toxic Gases, Combustibles, Sensitizers, Exothermic and Endothermic, Cryogens, Dry Ice, Compressed Gases (Hydrogen Nitrogen, Helium, and Fluorine Mix)
6.	Electrical	High voltage power supplies, hi amps, potential hot work
7.	Mechanical Hazards	Pneumatic lift, rigging; fork truck; powered hand tools
8.	Non-ionizing radiation	Induction heater (50 Kw, 40-200 KHz)
9.	Thermal Hazards	Cryogens, furnaces

CLUSTER: Materials Synthesis		
HIT Screening Question*	**HAZARD**	**SOURCE**
10.	Pressure Sources	Cryogen >160 L, >15 psig
11.	Noise	None
12.	Additional Hazards: biological, confined space, elevated	Welding/cutting
13.	Site built instrumentation	None
14.	Extended Operations	Work outside normal hours, will be attended
15.	Environmental	Hazardous waste, industrial waste
16.	Design controls, interlocks, ventilation	Local exhaust, interlock systems (laser lab)
17.	Facility Safety Systems	Sprinkler system, lightning/surge protection, compressed air, gases

* Corresponds to the Hazard Identification Screening Questions

Table 4-5

CLUSTER: Proximal Probes		
HIT Screening Question*	**HAZARD**	**SOURCE**
1.	Accelerators or RGD's	Incidental x-rays
2.	Radioactive Material	None
3.	Explosives	None
4.	Lasers	3b, 4, 2, 1, modified, laser dyes.
5.	Chemicals, toxic materials	Carcinogens, Pyrophoric, Toxic Gases, Combustibles, Sensitizers, Exothermic and Endothermic, Cryogens, Dry Ice, Compressed Gases (Hydrogen Nitrogen, Helium, and Fluorine Mix)
6.	Electrical	High voltage power supplies, hi amps, potential hot work
7.	Mechanical Hazards	Pneumatic lift, rigging; fork truck; powered hand tools
8.	Non-ionizing radiation	None
9.	Thermal Hazards	Cryogens
10.	Pressure Sources	Cryogen >160 L, >15 psig
11.	Noise	None
12.	Additional Hazards: biological, confined space, elevated	Welding/cutting; potential for biological samples, small quantity, sealed
13.	Site built instrumentation	Modified commercial equipment
14.	Extended Operations	Work outside normal hours, will be attended
15.	Environmental	Hazardous waste; industrial waste

CLUSTER: Proximal Probes		
HIT Screening Question*	**HAZARD**	**SOURCE**
16.	Design controls, interlocks, ventilation	Local exhaust; interlock systems (laser lab)
17.	Facility Safety Systems	Sprinkler system, lightning/surge protection, compressed air, gases.

* Corresponds to the Hazard Identification Screening Questions

Table 4-6

CLUSTER: Theory and Computation		
HIT Screening Question*	**HAZARD**	**SOURCE**
1.	Accelerators or RGD's	None
2.	Radioactive Material	None
3.	Explosives	None
4.	Lasers	None
5.	Chemicals, toxic materials	None
6.	Electrical	Standard commercial computer equipment extensive cable/cable tray arrangements
7.	Mechanical Hazards	None
8.	Non-ionizing radiation	None
9.	Thermal Hazards	Heat generation from 15—200 workstation computers on racks
10.	Pressure Sources	None
11.	Noise	None
12.	Additional Hazards: biological, confined space, elevated	None
13.	Site built instrumentation	None
14.	Extended Operations	Extended hours operation, unattended
15.	Environmental	None
16.	Design controls, interlocks, ventilation	None
17.	Facility Safety Systems	Sprinkler system, lightning/surge protection.

* Corresponds to the Hazard Identification Screening Questions

5.0 HAZARDS IDENTIFICATION

This section identifies those hazards that pose a threat to the workers or environment. No public threats are considered due to the negligible chemical and radiological inventories and the fact that this facility will be maintained as a radiological facility (below a Nuclear Category 3 facility).

The reader should note that the CFN Facility poses no new hazards not already encountered at BNL. Many years of design and operational experience lead to a high level of confidence that all significant hazards are identified and that controls will be put into place that have proven to be effective.

Non-operational hazards, like those associated with construction, are excluded except as they appear as external hazards. All traditional construction hazards are controlled by BNL safety procedures.

While detailed quantification of hazardous materials is not completely refined at this time, some quantification is possible based on instrument/equipment needs, and evaluation of similar current operations of the Principal Investigators. Chemicals expected include flammables, water reactives, corrosives and oxidizers.

Current and expected chemical inventories were evaluated against regulatory thresholds including Threshold Planning Quantities (TPQ) in 40 CFR 355, and the Threshold Quantities (TQ) in 29 CFR 1910.119 and 40 CFR 68.130. The predicted quantities to be used in the CFN are far below these regulatory thresholds. A screening using the Reportable Quantity (RQ) in 40 CFR 302.4 was also performed which identified quantities of chemicals that may approach RQ thresholds in a few cases.

Management of chemicals is very restricted at BNL using a Chemical Management System which inventories and tracks all chemicals from purchase to ultimate usage and/or disposal.

The CFN will not have any bulk storage of flammable or combustible liquids, corrosive, caustic, reactive, or toxic chemicals within the facility. All liquid and solid chemicals for experimental use will be stored in a central chemical area at the rear of the facility, near the loading dock. Chemicals will be transported in approved containers from the storage area to the laboratories. Liquid transfer of materials having an NFPA 704 hazard ranking of three or four will be transferred by safety cans complying with UL 30. Liquid containers exceeding 5 gallons will be transported on a cart or truck, however greater than gallon quantities will be a rarity. Within the laboratories, all quantities of chemicals will be restricted to necessary quantities only and stored in vented chemical cabinets.

The chemical storerooms will be designed to house approved chemical storage cabinets for each liquid and solid chemical type anticipated in the facility. Separate rooms will be provided for corrosive, flammable, oxidizing, and general chemicals. The rooms will be constructed of non-combustible materials and be provided with an exhaust ventilation system that has a minimum of 1 cfm per square foot exhaust to the outside without recirculation.

The chemical storage rooms will also be provided with automatic sprinkler protection. A combination safety shower/eye wash station will be provided in each storeroom as well as in the receiving area.

A storage bunker located at the rear of the facility will be utilized to store gas cylinders. These bunkers will segregate flammable gases from oxidizers and inerts.

Flammable and non-flammable gases will be used to support the research program including instrumentation support and will be in DOT cylinders with quantities limited to what is required for the process. Small quantities of toxic or highly toxic gases will be used and will follow BNL guidelines for the handling and use of toxic materials. The actual storage and delivery methodologies are still under investigation however will likely include the use of gas storage cabinets. These cabinets will be located at the rear of the facility, be exhausted to directly to atmosphere, be sprinkled, and have a gas detection and automatic supply shutdown system.

Several clusters will be conducting research on samples that may include biological material in small amounts. The facility will be designed to a Biological Hazard Level 2 and operations will comply with the BNL Biosafety Subject Area.

The CFN will not contain any accelerators but will introduce radiation generation devices capable of creating a radiological area. The RGD's are further discussed in section 6. No use of radiological materials is anticipated at this time, however there is a potential to introduce small amounts of radioactive materials/samples to support the experimental program or equipment containing radioactive sources. Any amount of radiological material will be maintained below 40 CFR 302 Table 302.4 Appendix B thresholds.

5.1 Anticipated Abnormal Events

Anticipated abnormal events are those events that are expected to occur in the facility one or more times during the life of the facility. Anticipated events are generally addressed through the design of the facility and standard operating procedures. Potential accident conditions are addressed through design, emergency response/recovery procedures and operator training/qualifications.

Anticipated abnormal events for the CFN facility are well understood due to the vast amount of experience with similar facilities at BNL. These abnormal events could include; equipment/instrument failure, chemical spill, sample spill, gas leak and power outage.

5.2 Maintenance and other Routine Events

Activities other than normal operations are considered in the CDR. These activities include repair and inspection activities of scientific equipment, routine maintenance, waste handling and management, and entry and exit to the facility.

Table 5-1 Operational Hazards

Hazard	Location	Comments
Lasers	Ultra Fast Optical; Materials Synthesis; Proximal Probes;	Multiple laser labs with class 4 lasers; interlock systems will be designed to BNL interlock standards.
X-Ray's	Nanopatterning; Ultra Fast Optical; Electron Microscopy; Materials Synthesis; Proximal Probes;	RGD's capable of producing a radiation area, potential for modifications to commercial equipment
Chemicals handling	Nanopatterning; Ultra Fast Optical; Electron Microscopy; Materials Synthesis; Proximal Probes;	All clusters will use laboratory quantities of chemicals; some use of carcinogens, toxins, pyrophoric, sensitizers and flammable gases will be used. Centralized segregated storage areas for chemicals and gases will be provided in the rear of the facility. Flammable storage cabinets and fume hoods will be provided for each cluster.
Mechanical	Nanopatterning; Electron Microscopy; Materials Synthesis; Proximal Probes	Power tools, hoists,
Thermal	Nanopatterning; Ultra Fast Optical; Electron Microscopy; Materials Synthesis; Proximal Probes;	Materials Synthesis will use furnaces with high surface temperature; warning signs will be installed. All clusters will use small amounts (<60 liters daily) of non-flammable cryogens.
Pressure	Ultra Fast Optical; Electron Microscopy; Materials Synthesis; Proximal Probes;	Compressed gases, vacuum systems
Hazardous/Industrial Waste	Nanopatterning; Electron Microscopy Materials Synthesis; Proximal Probes;	Low volume hazardous/industrial waste
Non-ionizing radiation	Nanopatterning; Ultra Fast Optical; Materials Synthesis	Up to 50Kw RF; stray magnetic fields
Electrical	Nanopatterning; Ultra Fast Optical; Electron Microscopy; Materials Synthesis; Proximal Probes;	Typical High Voltages and Currents associated with scientific instrumentation. Some equipment modification may be necessary and will require Electrical Safety Officer approval. Potential "hot" work will require adherence to BNL working hot procedures.

Table 5-2 External Hazards

Hazard	Location	Comments
Seismic events	Entire Site/Facility	A significant seismic event above the design level could cause structural damage and partial collapse leading to the loss of the facility, injury or death or personnel, and/or release of chemical material.
Flooding Events	Facility lower level	Flooding from surface runoff, systems failure or rain could cause flooding of the first floor.
High Winds	Facility	High winds in excess of the design wind basis could cause collapse of the roof allowing water and structural damage to the facility and support equipment with possible injury to personnel, and/or release of chemical material.
Snow Loading	Second level roof structure	Heavy snow loads in excess of design criteria could cause collapse of the roof allowing water and structural damage to the facility and its associated equipment, possibly leading to personnel injury and/or release of chemical material.

6.0 HAZARD ASSESSMENT AND HAZARD EVALUATION

This section assesses the hazards identified in section 5. A preliminary hazard screening was performed to identify potential hazards as potential preventive, mitigate features, and assign relative hazard level. The hazards for this operation are well understood because (1) similar operations are currently being performed in similar facilities with the same personnel who will operate the CFN facility and (2) all of the hazards realized in this facility have been effectively managed in other facilities at BNL and are considered routine.

6.1 Site Selection

The original site selected for the CFN was immediately east of the National Synchrotron Light Source (NSLS) building north of Brookhaven Avenue. The CFN was to have been connected to the NSLS by a connecting corridor and a covered walkway to instrumentation and would share a common loading dock and other support facilities.

During the initial CFN project investigations, a number of new factors emerged that forced a reconsideration of the site selection and an evaluation of the pros and cons of Site 1 (East of NSLS) and Site 2 (south of NSLS and south of Brookhaven Ave) See Title I design for details. Most of the factors were operational in nature e.g., future use, vibration reduction, and utility access. However, two factors did emerge that have a positive effect on ESH making Site 2 a superior location. These include soil contamination and traffic safety issues.

- Site 1 had some legacy soil contamination concerns. The original BNL firehouse was located in the northeast corner of the construction site. Previous remediation activities discovered small amounts of Cesium 137 and Strontium 90 contamination. This contamination was remediated, however as a precaution it was planned to sample prior to site excavation. This sampling would have been costly and could have led to construction delays

Several elements will be removed from the new site before new construction of the CFN: Building 193, the existing Credit Union, all paved surfaces on the building site including a section of Technology Street, and existing foundations from Building 318 that was previously demolished. It has been determined and documented that Site 2 has no legacy contamination thus sampling is not required.

- Site 1 was immediately east of the National Synchrotron Light Source (NSLS) building north of Brookhaven Avenue. The CFN was to have been a two-story facility connected to the NSLS by a connecting corridor and a covered walkway to instrumentation and would share a common loading dock and other support facilities necessitated by the congested area. This site was also in close proximity to Railroad Ave directly to the east. This congestion was a potential concern not only from an operations standpoint (vibration control) but also raised a concern from a vehicle traffic flow and limited parking standpoint. Site 2 encompasses a much larger footprint and eliminates this concern.

6.1 Facility Hazard Categorization

Facility hazard categorization is based on the radioactive and chemical inventory within a facility and the associated hazard potential. Hazards are evaluated in compliance with U.S. Department of Energy (DOE) Order 5480.23, "Nuclear Safety Analysis Reports;" DOE Standard 1027-92, "Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23;" and 29 CFR 1910.119, "OSHA Process Safety Management of Highly Hazardous Chemicals" and the BNL Subject Area on Facility Hazard Categorization. The Facility Hazard Category determines the type of facility and subsequent requirements for safety documentation, authorization basis, and approval authority for operation of the facility.

The CFN facility has been classified as a radiological facility per BNL Facility Hazard Category Subject Area. Chemical inventories do not exceed the threshold for designation as a chemical facility. As a radiological facility inventories must be maintained to less than nuclear category 3 levels as per DOE Std 1027-92. Although the facility has a negligible radiological inventory, the CFN has been designated as a radiological facility based on use of Radiation Generating Devices (RGD's) that have the potential for creating radiological areas and personnel exposures. There is also contingency equipment proposed that may contain radioactive sources. This categorization will be revisited when equipment specifications and initial testing is completed.

6.2.1 Natural Phenomena Hazards Mitigation (NPH) Performance Category (PC) Determination

Based on the guidance in DOE Std 1021-94, the natural phenomena hazards mitigation Performance Category (PC) for this facility based on the identified hazards and potential consequences is PC-1.

6.3 Methodology

Hazards identified in the screening process are evaluated in context with the proposed operation description, the hazards associated with the current operations with similar facilities at BNL, and the baseline knowledge of these types of hazards.

Qualitative hazard assessment is predicated on the terminology used in DOE Order 5481.1B. Although this Order is no longer in effect, these qualitative hazard levels and consequences are a well-accepted methodology for categorization of hazards.

Table 6-1. Qualitative Hazard Levels

Hazard Level	Narrative Consequence
High (H)	Potential for onsite or offsite impacts to large number of persons or for major impacts to the environment.
Moderate (M)	Potential for considerable onsite impacts to people or the environment, but at most only minor offsite impacts.
Low (L)	Potential for only minor onsite and negligible offsite impacts to people or the environment.

6.4 Hazards Evaluation

The assumptions used in determining the qualitative hazard levels are:

Operational Low hazards exist due to worker exposure to radiation generation devices and lasers, and external low hazards from natural phenomena hazards. Standard industrial hazards are considered low and although they were identified in the preliminary hazard screening, they are not addressed in detail in this analysis due to the Laboratory's institutional, facility and activity levels controls in place at to control these hazards see section 7.

No high or moderate hazards have been identified for this facility.

Several low consequence hazards were identified. Although these hazards are considered routine at BNL, they are discussed in this section to help identify necessary controls that are required to be incorporated into the design phase. The low consequence hazards are:

- Worker exposure to lasers
- Worker exposure to radiation generation devices
- Natural Phenomena Hazards

6.4.1 Laser Hazards

Three of the laboratory clusters (Materials Synthesis and Ultra Fast Short Wavelength Source, Proximal Probes and Optical Microscopy) will require laser labs that will contain class 4 lasers. The Laser Safety Subject Area requires that Class 4 lasers have their controlled areas interlocked. ES&H Standard 1.5.3, Interlock Safety for Protection of Personnel, details the requirements for technical design, hardware, testing, and documentation for these systems. As guidance from ES&H for design basis requirements, the level of protection category for Class 4 laser systems is for "critical" hazards and the design probability for their failure is considered "remote."

The CFN laser laboratory interlocks will follow the subsequent general design criteria for specific hardware requirements due to the "Critical" hazard area designation.

This requires that an appropriate entry control program shall be established. The fail-safe character of the interlock system is vital. The entry control program shall include at least one of the following. One item alone does not necessarily constitute an adequate interlock system; therefore, review and approval of the Laser Safety Officer will be required prior to final design.

a. The interlock system shall prevent entry to the area when Critical Hazards exist, or upon entry, shall cause the hazard level to be reduced below that level defined as critical; also, it shall prevent restart of the energy source until a manual reset is made.

b. Control devices shall activate a conspicuous visible or audible alarm if the hazard remains, so that the individual entering the Critical Hazard Area through a control device is aware of the energy level and the Area Supervisor or designee are also made aware of the entry. Administrative procedures shall define the required actions of personnel when alarms are activated.

c. Entryways shall be locked during operations, except when access to the area is required. Positive requirements for entry including surveys of hazardous energy levels shall be made for the initial entry, and periodically, as necessary, to assure that safe energy levels are maintained in accordance with administrative procedures.

4. Control devices shall automatically generate audible and/or visible alarm to alert personnel in the area before the use or operation of the energy source. These alarms shall allow sufficient time to evacuate the area, or to activate a secondary control device to prevent the use or operation of the energy source. If the visual indicator should be turning out the lights, levels of illumination shall be high enough so that personnel can rapidly leave the facility or take action to prevent actuation of the hazardous energy.

The technical design requirements for the CFN laser labs will follow the following:

1. The protective functions of the interlock system should render the energy source/system safe during the most likely failure events (e.g., loss of power/pressure, open circuit, short to ground, and single component failures).

2. Redundant circuits should not share cables and should be separated physically on circuit boards and terminal strips. Redundant systems should be configured differently.

3. Cable runs should be made in accordance with good practices and the National Electric Code.

4. Suitable protection shall be provided to preserve the physical integrity of all system components. Components and materials should be resistant to damage from heat, radiation, and water, as appropriate.

5. A configuration management program shall be established to include the interlock system logic and also interfaces to peripheral equipment, such as power supplies for instrumentation.

6. All interlock lines and components should be labeled and readily identifiable.

7. The interlock system should be modular in design so that the interlocks for different parts of the facility can be serviced independently. If the facility is designed to allow portions to be serviced or modified while the remainder is in operation, such as individual experimental areas, then there shall be a means to reconfigure/disconnect the part of the interlock system which is being serviced from the rest of the system without compromising safety.

8. The design of the interlock system shall provide for complete testing, with the effort and disruption required by such tests within practical limits.

9. There shall be an independent review of the interlock system's design by persons experienced in the design and operation of personnel protection interlock systems. There shall be a record kept of the findings of the review and the response to each finding.

10. A controlled means for reconfiguration and bypassing of components of the interlock system shall be established and documented.

11. A well-designed interlock system for Critical hazard systems should include sequenced and timed inspection stations, warning lights, audible alarms, and emergency off- switches.

12. Where practicable, indication of the status of the facility interlocks shall be shown on the control console.

13. Emergency-"Crash"-devices shall be provided, and shall be clearly visible, labeled, and readily accessible. Activation of emergency devices in the Interlocked Area shall re-initialize the system and require a reset at the location of the activated emergency device.

14. Emergency exit shall be possible at all doors in conformance with NFPA 101, Life Safety Code. Emergency entry into the area also should be provided.

15. Status signs or clearly labeled status lights should be provided at entry doors.

16. Where personnel entry is possible, Interlocked Areas shall be searched before the energy source is turned on to insure that there are no people still inside. Where appropriate the following shall apply.

    a. Sequential-search confirmation buttons, or check stations, shall be placed to insure that the area is comprehensively searched. These check stations also may be used to set the interlocks on the doors as they are passed. If any door is opened after being set, or any emergency device is activated inside the interlocked area, the system logic shall abort the search.

    b. After completing the search, there shall be both audible and visible warnings providing a time interval before enabling of the hazardous energy. Warnings shall be limited to within interlocked areas to avoid de-sensitizing personnel. If the lights are dimmed as the visible warning, then the level of illumination shall remain strong enough for personnel to see clearly, to rapidly leave the facility or take action to prevent actuation of the hazardous energy. The duration of the warning interval shall be sufficient for an individual to reach an emergency "crash" device or to leave the area.

    c. The search procedures must be rigorous and carefully designed, and shall be tested periodically.

6.4.2 Radiation Generation Device Hazards

The CFN will utilize RGD's in the following clusters; Nanopatterning, Ultra Fast Short Wavelength Source, Electron Microscopy, Materials Synthesis; Proximal Probes that are capable of producing radiological areas and electron-generating devices that are capable of producing incidental x-rays. For the most part these will utilize commercial shielded instruments that will reduce the dose to an acceptable level, however in certain cases, modifications to the instruments may be necessary to support the science mission. Due to this potential, the CFN will incorporate design guidelines from the BNL Radiological Control Manual.

Special considerations associated with the use of radiation generating devices include the presence of x-rays incidental to operation and the potential for uncontrolled exposures. Operation of these devices requires stringent physical and administrative controls to prevent unnecessary exposure to operating and support personnel. The following requirements will be applicable to the RGD's used in the CFN.

1. BNL Radiological Control Manual and BNL RGD site wide procedure.

2. Safety devices and interlocks at fixed installations shall be operational prior to and during generation of a radiation field. Operational status shall be verified by testing.

3. General Operational Safeguards.

   The Departments/Divisions are responsible for implementing the following recommendations, which are applicable to analytical X-ray units, utilizing either closed or open beam diffractometers and spectrographic equipment.

   a. Each facility containing analytical X-ray equipment should have a listing of responsible persons posted conspicuously at the entrance to the facility or laboratory.

   b. A warning light of fail safe design labeled with the words **"X-Rays ON"** shall be conspicuously located near the X-ray tube to indicate when the X-ray tube is activated.

   c. A sign or label indicating **"CAUTION--X-RAYS PRODUCED WHEN ENERGIZED"** should be placed near any switch that energizes an X-ray tube.

   d. The dose due to unwanted radiation from components such as high voltage rectifiers shall not exceed 10 mrem in a week in any accessible region 5 cm from the outside surface of the generator cabinet. Assuming that an individual may be in the vicinity of the equipment while it is operating for as long as 40 hours per week, the dose rate should not exceed 0.25 mrem/hr.

   e. Normal operation procedures and alignment procedures shall be documented by the manufacturer of the X-ray system, or by the facility manager if the source housing and X-ray accessory apparatus are not compatible components supplied by the same manufacturer.

   f. All safety devices (shutters, warning lights) should be tested quarterly to ensure their proper operation. Records of these tests should be maintained.

g. Any attempt to alter safety devices either temporarily or on a permanent basis shall be approved by the facility manager and warning of the alteration conspicuously posted. Radiation protection surveys should be made after each alteration of safety devices.

h. Radiation protection surveys should be conducted in the immediate vicinity of the X-ray apparatus by qualified personnel on a routine basis. These surveys may be performed by the operator with the guidance of the Rad Con Representative.

i. Operators of analytical X-ray equipment shall be required to use finger dosimeters of other personnel monitoring devices provided by Facility Support Services.

4. Closed Beam Diffractometers and Spectrographic Equipment

a. The radiation source, sample, detector and analyzing crystal (if used) shall be enclosed in a chamber or coupled chambers that cannot be entered by any part of the body during normal operation.

b. The inherent shielding of the chamber walls shall be sufficient to limit the dose rate in all regions 5cm from its outer surface to 0.25 mrem/hr during normal operation.

c. The sample chamber closure shall be interlocked, by a fail-safe method, with the X-ray tube high voltage supply or a shutter in the primary beam so that no X-ray beam can enter the sample chamber while it is open unless the interlock has been consciously and deliberately defeated and conspicuously posted.

6.4.3 Natural Phenomena Hazards

Site selection and facility design must consider the relevant natural phenomena hazards. Those hazards of interest to this project include seismic events, flooding, high winds and snow loading. All Natural Phenomena Hazards are considered to be Low hazard.

6.4.3.1 Seismic Events

The effects of a significant seismic event at BNL would include loss of facility, personnel injury, and some loss of chemical materials. Because there are no inventories of radionuclides, no releases are possible. A seismic event, would likely cause loss of the facility and instrumentation.

The BNL site was originally designated as a "moderate" seismicity zone as per Interagency Committee on Seismic Safety in Construction (ICSSC) Technical report 17. This ICSSC report designated a "moderate" zone as one having an acceleration velocity between 0.10 g and 0.20 g, with a "low" zone being below 0.10g. A more detailed analysis using the county-by county maps from the 1994 NEHRP Recommended Provisions for the development of Seismic regulations for New Buildings was used as allowed by the ICSSC report. This evaluation shows that BNL falls into an area where the acceleration velocity is slightly less than 0.10g, and thus has been reclassified as a "low" seismicity zone. The design for the CFN Facility is based on a 0.20g acceleration velocity. The building structure will be designed for maximum rigidity by using generously sized structural members, rigid connection details, beam, and girder framing of the second floor with 8" thick concrete fill. Due to the vibration sensitivity of many of the instruments, Vibration isolation slabs will be used in the construction, this feature will help to protect instrumentation during a seismic event.

The probability of occurrence in the BNL area of an earthquake sufficiently intense to damage building structures was thoroughly investigated during construction of the Graphite Reactor and several subsequent reviews for the High Flux Beam Reactor, all within close proximity to the proposed site of the CFN. It is the consensus of seismologists that no significant quakes are to be expected in the near future. No active earthquake-producing faults are known in the Long Island area.

6.4.3.2 Flooding Events

The only water of any potential significance on the BNL site is the Peconic River, on the North-Northeast side of the site. The Peconic is frequently dry, and there is no record of the river producing any flooding that could encroach on the site. Therefore, flooding from surface water sources is not considered a concern.

As evidenced in the Brookhaven National Laboratory Site Environmental Report for Calendar year 1993, there is potential for the groundwater to rise to the surface in certain areas of BNL. According to this report, groundwater has risen to the ground surface at several locations on site. Groundwater is generally 35 to 40 feet below ground surface around the site and therefore not considered a flooding threat.

While BNL is relatively near the coast, there has been no Tsunami flooding of the area recorded. The effect of Tsunami flooding is not applicable. While there can be mild ice rain in the vicinity of BNL, it is not expected that the site will experience any severe ice jam, flood, wind-driven ice ridges, or ice produced forces that would effect the CFN facility.

The CFN Facility will be located at base level (first floor) of approximately 77'-0" above sea level. Flooding is not considered a major threat to the CFN facility due to the site characteristics and the elevation of the facility. Any potential flooding is most likely to be from leaking facility systems.

6.4.3.3 Snow Loading

Heavy snow loads are possible but infrequent due to the temperature being moderated by the Long Island Sound to the north and the Atlantic Ocean to the south. The effect of snow load beyond the design capacity of the roof of the facility is most likely to occur to the upper floor and mechanical equipment penthouse. This could result in possible damage to instrumentation. These consequences are considered minimal and would not warrant design beyond what is required to meet the applicable Building Codes.

The facility will be constructed of reinforced cast-in-place concrete floors, steel frame with insulated metal panels and thermal glazing. The function of the structural systems is to provide the support for the structures to resist all anticipated roof and wind loads, and all loads produced from the mechanical and electrical utilities within the facility. The building will be designed to a ground snow load of 45 psf and a design snow load of 30 psf plus drift where applicable.

6.4.3.4 High Winds

The highest wind speeds at BNL have occurred with hurricanes. Hurricanes occur in June through October and a few weeks of declining storms in May and November. In September, there is a 92% probability for at least one tropical cyclone somewhere in the North Atlantic and a 42% probability for three or more. The northeastern states were subject to hurricanes of moderate intensity only rarely between 1901 and 1931. Sections of the coast have been severely affected since 1932, with several hurricanes moving inland or passing close enough offshore to result in storms of hurricane winds, heavy rainfall, or high storm tides. However, tornados and hailstorms are extremely rare on Long Island.

High winds have been analyzed at BNL for collocated facilities to the proposed location of the CFN (HFBR and BGRR) and have been bounded by hurricane winds of up to 110 mph. These analyses showed that any events associated with the high winds were not expected to result in any impact that would release radiological inventories of those facilities. The CFN with a much smaller profile and construction methods meeting the UBC would be bounded by those previous analyses. The design basis wind used for this facility will be a basis wind speed (3 second gust) of 120 mph.

If wind damage did occur to the roof structure, the consequences would be similar to that of the heavy snow loading where damage to instrumentation is possible but would not result in a release the hazardous material inventory of the facility.

7.0 ADMINISTRATIVE CONTROLS

This section contains the administrative controls that are indicated by the analysis or are required to maintain the assumptions associated with the analysis. This is not an inclusive listing of necessary administrative controls due to the fact that many of those will be controlled by the existing Laboratory Management Systems. The controls listed here are those that may affect the authorization basis of the facility and the validity of the PHA.

7.1 Inventory Control

The fundamental basis of this facility is that it is to remain below a nuclear facility categorization. An inventory control system will be implemented to ensure that the radiological inventory remains below a category 3. Chemical inventories are limited to the minimum amount necessary to support the experimental program. Controls will be established to assure that quantities in any one zone or collective for the building do not exceed the limits set forth in the building code. Chemical inventory is tracked through the Chemical Management System.

Due to the proposed manifolding of the fume hoods administrative controls will be necessary to assure the compatibility of materials used in the hoods. While separate exhaust systems will be required for any radioactive materials or perchlorite material the general use hoods will be manifolded together and be used for a Varity of chemicals. As part of the experimental safety review process, all materials used in the facility will be evaluated for hazard and controls including incompatibilities with other materials.

7.2 Radiation Protection

The existing Laboratory radiation protection program will be in effect for the CFN Facility, which is in compliance with 10CFR835.

7.3 Access Control

The CFN management will establish appropriate access controls to ensure that access to the facility is controlled when hazardous conditions exist.

7.4 Transportation and Handling of Hazardous Materials

The CFN will follow the Laboratory Transportation and handling of hazardous materials program. Samples will be controlled by standard operating procedures that will cover handling, packaging and transportation to and from the facility. These procedures exist for other BNL facilities and will be modified to accommodate CFN Operations. Emergency procedures will be established for the CFN Facility to address releases of hazardous material, exposures of personnel, fires etc.

7.5 Fire Hazard Controls

Combustible loading will be managed to ensure that no unnecessary flammable materials accumulate in the facility or that unnecessary flammable materials are introduced to the facility. Fire detection systems will be installed and maintained to assure that they are operational and function as designed.

7.6 Configuration and Change Management

The CFN facility will establish configuration and change management systems to ensure that identified safety systems are maintained in suitable state and that changes do not adversely affect the facility safety operations.

7.7 Training and Qualifications

The CFN will follow the Laboratory Training and Qualifications Program this program is to ensure that BNL employees, guests, users, and contractors are trained and qualified to perform their assigned tasks and job functions. The Laboratory has established training requirements in accordance with regulatory requirements for work to be performed, hazards that may be encountered, areas that will be accessed, potential for risk, and general site requirements. BNL has defined minimum training requirements for work to be performed, and monitors the completion of these requirements. In addition to ensuring that personnel receive appropriate training, the Laboratory is committed to ensuring that its workers are qualified to perform their jobs.

Qualification is defined in terms of education, experience, training, and any special requirements (e.g., medical exams, external certification) necessary for unescorted, unsupervised performance of assigned responsibilities.

7.8 Work Planning and Control

All work performed at the CFN including experimental, routine work and maintenance will be covered by utilizing existing Laboratory Subject Area "Work Planning and Control".

This subject area establishes work control processes based on the Integrated Safety Management (ISM) Core Functions to define the scope of work, identify the hazards, develop controls, work within the controls, and provide feedback and continuous improvement. The subject area provides a graded approach to manage a wide range of operational and experimental activities from routine to highly complex, and integrates other systems and subject areas such as hazard analysis tools, training requirements, and environmental management into the processes.

The significant aspects of this Subject Area with applicability to the CFN are as follows:

1. **Experimental Safety Review** - All organizations conducting experiments use this process to identify the hazards, plan the work controls, and authorize the experiment. The process provides a graded approach to determine the level of planning rigor needed in the documentation. Each Department/Division uses an Experiment Review Coordinator to determine if a proposed or modified experiment requires a new Experiment Safety Review Committee review or if it fits within established controls from previous reviews.

2. **Work Planning and Control for Operations** -This process applies to all physical work performed by BNL and non-BNL staff, and also uses a graded approach to identify hazards, risks, and complexity levels, and to establish the level of rigor for planning and review. The process requires use of a site-wide work permit form for all moderate and high hazard work, not already covered in Standard Operating Procedures, to key the work control process.

7.9 Chemical Management

BNL has an established Chemical Management System (CMS) in place. The CMS consists of a web-based inventory that captures incoming chemicals (type, quantity and location) to the site with bar code identification and tracks these chemicals through their use and ultimate disposal. All chemicals used at the CFN will be tracked in this fashion.

7.10 Authorization Basis

Although a Safety Analysis Report is not required as an Authorization Basis (AB) document due the radiological hazard categorization of this facility, BNL uses a Facility Use Agreement (FUA) program to document the AB of facilities. The FUA will establish the operational parameters, and required hazard and risk analysis, safety envelope, and the authorization basis for the CFN facility. The FUA will be established prior to the Operational Readiness Evaluation that is required prior to occupancy,